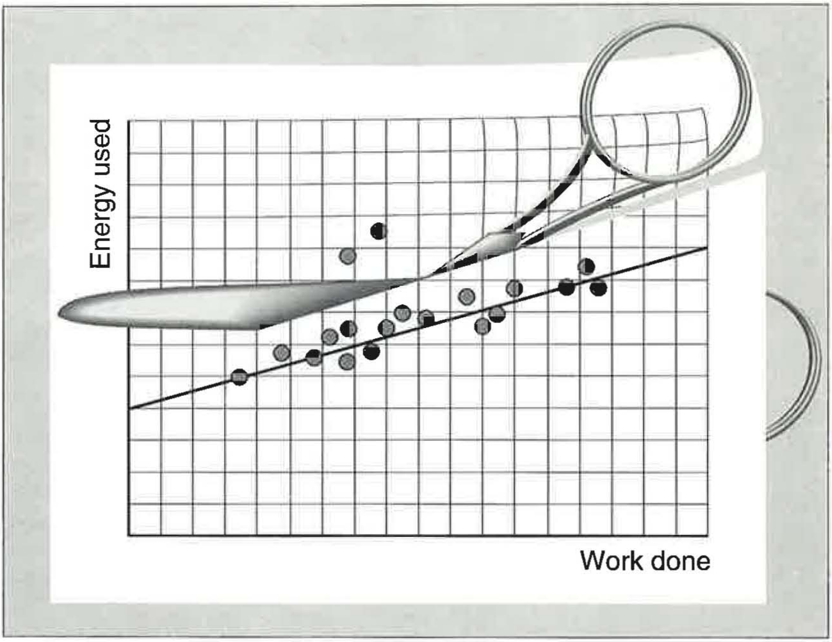
DEPARTMENT OF THE ENVIRONMENT, TRANSPORT AND THE REGIONS

FUEL EFFICIENCY BOOKLET 13

Waste avoidance measures



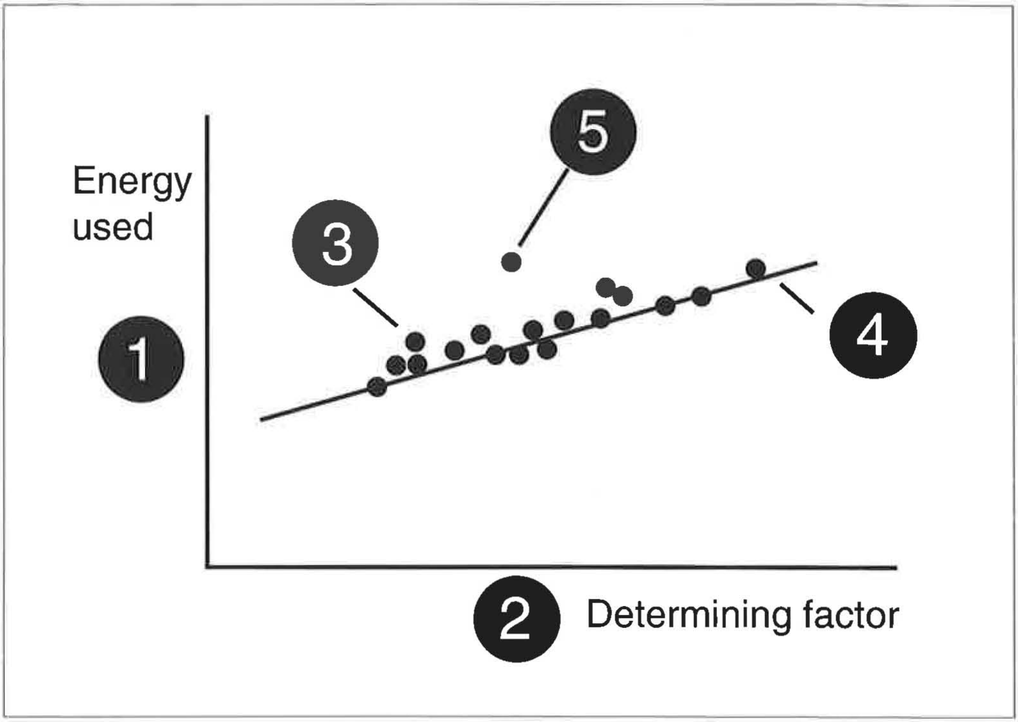
ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

The views and judgements expressed in this Fuel Efficiency Booklet are not necessarily those of the Department of the Environment, Transport and the Regions (DETR), ETSU or BRECSU.

Contents

Waste avoidance at a glance



For each stream of consumption you want to monitor, measure **(1)** the amount used each month (or each week) along with **(2)** the corresponding value of determining factor (production throughput, degree days, or whatever). Plot one against the other **(3)** as shown and draw a straight line **(4)** near the lower edge of your observations. Thereafter, if any significant avoidable waste occurs, it will result in a point **(5)** falling well above the target characteristic line.

1. Introduction

Waste avoidance is a much-neglected route to energy cost reduction. But, if you know how to implement it, you can readily exploit the opportunity which it presents to increase profits.

Waste avoidance is a simple concept to understand. For any given building, process or vehicle there is a level of energy consumption (relative to the required conditions, production output or duty performed) which represents efficient operation. This will occur when all systems are functioning as intended and where occupants, operators, drivers and maintenance staff are using plant, systems and controls correctly. As soon as there is any deviation from this ideal, one of two things will happen: either there will be a drop in energy consumption accompanied by loss of service, or energy consumption will increase, probably without any symptoms evident to those concerned. Such an increase in consumption is unnecessary and therefore constitutes avoidable waste.

Avoidable waste, as the term implies, is quick and cheap to cure. It can be eliminated without disruption: often it is as easy as restarting a stopped timeswitch. Most importantly, avoidable waste can be cured without anybody noticing – you will merely be preventing the purchase of energy that wasn't doing anything useful.

Why is this booklet necessary? Simply because experience suggests that (a) all businesses are either paying for avoidable waste now, or are vulnerable to its unexpected onset; and (b) very few managers realise how much hidden value there is in commonplace business statistics like meter readings, production volumes, and degree-day data. This is the beauty of the waste avoidance technique we are going to describe: it merely relies on data you are probably already collecting.

The context of waste avoidance can be seen from Fig 1, which illustrates some of the tasks involved in managing energy in its various facets.

For present purposes, let us put to one side the issue of price reduction, and concentrate instead on volume reduction activities. These, of course, are the ones which reduce our environmental impact as well as increasing our profitability.

Under the 'minimise consumption volume' branch in Fig 1, there are two options, namely to improve underlying efficiency and to avoid wasteful operation.

Improving underlying efficiency is all about energy surveys and capital investment projects. It is nearly always a technical activity - often business - specific. It is also perceived as risky, and indeed some projects do fail through inappropriate application or poor management.

By contrast, an attack on costs under the heading 'avoid wasteful operation' can easily be very cost effective and risk-free for those who are prepared to confront not just the technical issues, but also people-related issues like training of operators.

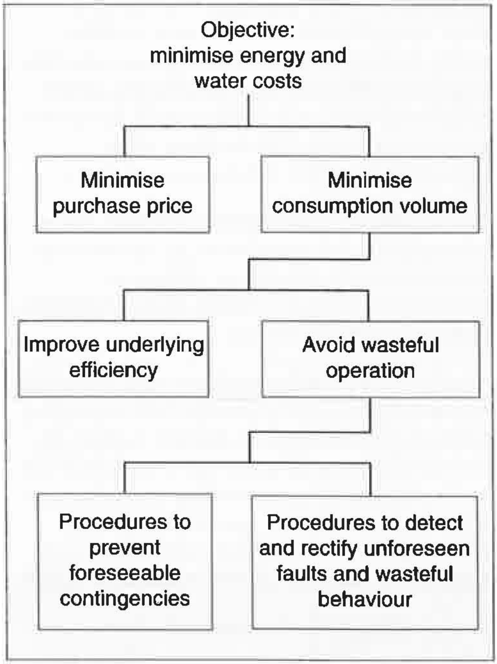


Fig 1 This diagram attempts to categorise some of the tasks facing the energy manager. Action on price and underlying inefficiency have been well publicised in the past; waste avoidance complements these activities by detecting and resolving unexpected adverse changes in performance

Training, however, is limited to eventualities that can be foreseen. It is also necessary to allow for the unexpected: and this is where waste avoidance

comes into its own. As you will learn later, avoidable waste nearly always causes unexpected change in patterns of energy use and the key to detecting avoidable waste lies in adopting methods of analysis which help you see such unexpected changes clearly.

2. Principles of waste detection

When unexpected waste first occurs, it changes the way the affected system consumes energy. Knowing the normal pattern of consumption, and then watching for deviation from normal behaviour, enables the user to detect when something has gone wrong.

Many good energy managers instinctively understand this idea and apply it in situations where 'normal' performance is easy to define, notably those cases where consumption varies little from one month to the next. When every month should be the same, a deviation is easily recognised, as anyone will agree who monitors water consumption in office buildings, for example.

Unfortunately, in most real-life situations, energy consumption is not steady from one month to the next, but varies in response to changes in production throughput, weather, hours of daylight, or other determining factors.

There have traditionally been two ways of dealing with such fluctuations in demand, both attempting to remove the variability. In the first method, the consumption in any given month is compared with consumption in the corresponding month the year before (the 'year-on-year' method). The other method removes the seasonal variations by using an annual moving average (the smoothing method).

The smoothing method is extremely slow to react to changes, whilst the year-on-year method tends to give wild reports because there is usually less consistency from year to year than one would like. Both methods are completely compromised by any instance of poor performance, because the resulting unrepresentative month precludes any valid analysis a year later.

Today, smoothing and year-on-year analysis need only be used as a last resort. An alternative method, which is presented in this booklet, is based on the idea that you use energy for a purpose, and by measuring the extent of the duty performed you can infer the theoretically correct quantity of energy. This you then compare with the amount you actually used. Let us cite a simple example: you buy petrol for the purpose of propelling your car, and the mileage driven dictates the amount of petrol needed. Likewise in a factory making paper, the quantity of paper produced in a given month dictates the amount of steam required in, say, the stock preparation plant. In an office building, how cold the weather is determines how much heating fuel is required, and the number of hours of darkness determines to some extent the demand for electricity.

These simple and perhaps obvious examples serve to illustrate the general idea that in most cases the expected 'ideal' consumption of energy for any given duty can be calculated by measuring the appropriate determining factor and applying a suitable formula. For instance: if you normally get 35 miles per gallon (mpg) of petrol and in a given month you drive 1,750 miles, you would expect to use 50 gallons of fuel. If you found that you actually bought 54 gallons you would suspect that something was wrong.

The example of a car is a convenient one to start with because (given consistent maintenance and driving habits) the ratio of fuel used to miles driven does not change with mileage. It makes sense to monitor mpg as a management measure, because it is a 'parameter' (something which does not normally change).

In most other scenarios, the same consideration does not apply. Simplistic ratios such as 'therms per tonne' or 'kWh per degree day' are notoriously fickle as management measures because they are variable (1). This is because most energy-using systems have a constant (time-related) element. Take a building with gas used for heating and hot water. It will have both a fixed monthly demand (for domestic hot water, plant standing losses, etc) and a variable demand proportional to the degree-day value (see reference 2, and also the degree days box on page three). The figure for kWh used per degree day varies because the fixed component is being divided by a variable degree-day value. Since it is infinitely easier to manage if one has a fixed target to aim for, how can we arrange matters so that the target figure does not vary?

Degree days

The degree day count, which is calculated from measurements of outside air temperature, is a measure of how cold it was over a given period in a particular region.

Their calculation is deliberately designed to yield a figure which accurately predicts the demand for heating fuel.

Regular monthly reports are provided for numerous observing centres around the UK; fuller details are given in reference 2.

The answer lies in splitting the target into its two component parts: a fixed part (or base load) and a variable part.

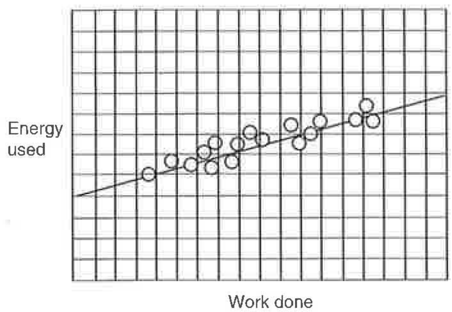


Fig 2 The crux of waste avoidance is that the amount of energy used ought to be consistently related to the work done

Fig 2 shows how the target for an energy-consuming system is set as a simple straight-line relationship. Knowing the work done, A (often referred to as the 'determining factor'), the energy requirement T can be estimated from the straight-line formula:

$T = k_0 + k_1 A$

where k_0 and k_1 are parameters: they are a pair of constants unique to the system being studied. We are interested in the difference between this estimate, T, and the actual consumption for the period concerned.

Case study 1

In 1994, the *Guardian* reported a case where a borough council engineer had detected unexpected increases in water and electricity consumption in a number of public conveniences.

In one case, the fault was commonplace: a faulty valve on the urinal flushing system. But in several other cases, the excess water consumption was found to be attributable to vagrants inadvertently triggering the automatic flushing system, which was controlled by motion sensors.

The story on electricity consumption was similar: the nocturnal inhabitants were using the hand driers to warm themselves. But the twist in the tale came when a lavatory attendant was found to have installed a fan heater in a service duct. Even for the reader who thinks that persistent intruders might have been anticipated as a cause of excessive water use, it is impossible to argue that the actions of the attendant were anything but unexpected.

The amount the council saved by detecting and resolving the situation was stated to be £4,000 per year.

In the remaining sections of this booklet we will examine how analysis of this difference is used in the detection of avoidable waste. We will begin with a discussion of how to set the position of the performance characteristic line for targeting, and then explain how changes in behaviour can be diagnosed by tracking any subsequent movement of the line.

After examining some refinements and variations which may be useful in certain circumstances we will consider software assistance, and go on to look at: the issues involved in operating a waste avoidance scheme; investigating incidents of suspected waste; and measuring the savings achieved.

The applicability of the technique to non-energy consumables will be mentioned and we will finally review certain complementary activities — simple vigilance, efficiency benchmarks, training, awareness and staff motivation.

3. Simple target setting

We have introduced the idea that a target for performance can be set by means of a straight-line relationship between energy used and some relevant determining factor. The question then arises: how can the most appropriate target be set?

In principle (if not in practice) one could do a detailed survey of the building or process in question, and work out its energy demand pattern from first principles. This will obviously be time-consuming and indeed in many cases we will be frustrated by lack of vital data, or just our own incomplete knowledge.

Another approach is to compare like with like. This is the thinking which underlies normalised performance indicators (NPIs) and specific energy ratios (SERs) which seek to define targets based on averages of large populations of similar buildings (or processes, as the case may be). Unfortunately a SER or NPI may yield a misleading target because it ignores the specific features of the case under study, and thus can easily be either unattainable or too lenient.

There is a method both simpler and quicker than either of the preceding approaches, with the advantage that it yields a target which is both aggressive and achievable. It uses evidence of best past performance as a guide to future targets.

The steps required are these.

1. Decide on a convenient reporting interval (most people use either a weekly or monthly cycle, but a daily, per-shift, or per-batch basis would be possible).
2. Decide what factor causes the variation of consumption volume in the stream you are studying. Fig 3 gives a small selection of examples.
3. Working through your back records, tabulate the weekly or monthly consumption volumes in one column and the corresponding values of the determining factor in another.
4. Plot energy consumption against determining factor on an *x-y* plot as shown in Fig 4.
5. Also as in Fig 4, draw a straight line near the lower edge of the scattered points. This becomes your target performance characteristic line, against which all future consumption will be judged.

Commodity	Duty performed	Possible factors
Electricity	Outside security lighting	Hours of darkness
Water	Swimming pool make-up	Number of bathers (because of evaporation and water removed in swimming costumes)
Gas	Space heating	Heating degree days
Electricity	Air conditioning	Cooling degree days
Oil	Steam-raising in boiler plant	Amount of steam generated
Electricity	Air compressor	Air volume delivered
Diesel road fuel	Goods vehicle	Tonne-miles hauled
Steam	Production process	Production volume

Fig 3. Examples of determining factors. The things which can be used as determining factors in waste avoidance analysis are as varied as the duties to which energy and water are put. The selection is merely a guide to the variety of factors which may be considered

The positioning of the target performance characteristic along the lower edge of the scattered points, rather than using best fit through the middle, often prompts scepticism or even criticism. But it is crucial to the method.

The logic of using the lower edge can be argued in two ways. One is to say that points at the lower edge represent achievement of the least energy consumption for a given value of determining factor. The other argument says that if the straight line represents what can actually be achieved, any deviations are far more likely to be above the line than below it. This coincides with common experience: when energy-using systems go wrong, they usually fail on the excess consumption side.

Any failure resulting in lower-than-expected consumption will have an immediate detrimental impact on output, comfort or quality, and will be picked up and corrected without the need for routine monitoring; imagine an immersion heater element failing, or a heating time switch stopping in the 'off' position.

The method described can easily be implemented using pencil and paper since one is merely looking for the occurrence of a point plotted significantly above the target performance characteristic. The cost of an unexpected deviation can quickly be worked out by measuring how far above the target performance characteristic the plotted point falls, and multiplying this volume measure by the unit price. Appropriate steps can then be taken to find and remove the cause.

Graphs for use in waste avoidance schemes

There are perhaps five kinds of graph which are particularly important in waste avoidance. The first is the scatter diagram or 'x-y' plot (Fig 4) where consumption is linked to an identifiable determining factor such as production volume. Here the vertical axis represents the amount of energy used and the horizontal axis represents the volume of determining factor. Each week or month, a new point can be plotted. As we have already seen, the relationship between consumption volume and determining factor can be deduced, and can be represented by a straight line.

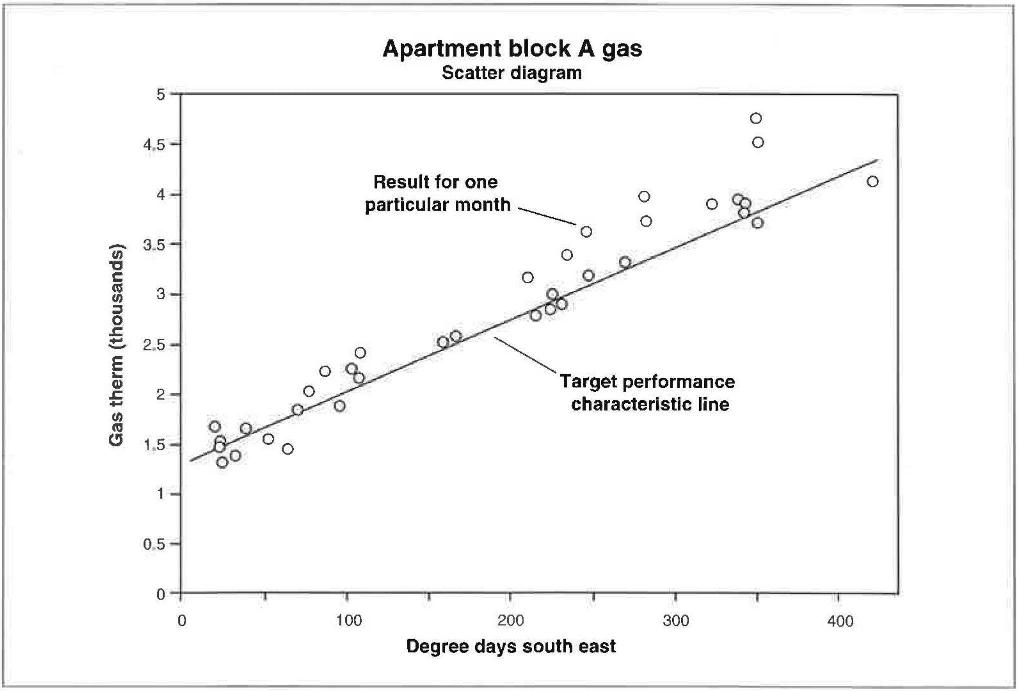


Fig 4 Individual monthly observations plotted on a scatter diagram, in this case gas volume versus degree days. The solid line is known to be achievable; points significantly above the line represent the occurrence of excessive consumption

The target performance characteristic line is the crux of the method because it allows you to back-calculate the monthly target energy consumption from the value of determining factor (production volume, degree days, etc). The next type of graph is the trend (the solid line in Fig 5), in which each successive point is the average of the previous twelve months individual values.

The trend line was described in section 2 as a 'last resort'. This is because it ignores the effect of any determining factor such as degree days or production volume, which we now know we can account for properly by setting a target performance characteristic. Where the trend line has some value, is where consumption volumes are determined by erratic influences (or by factors which we cannot practicably measure). The moving average used to calculate the trend has a smoothing effect which reduces the impact of the random or unmeasured influences. General electrical supplies to offices, and gas for catering, are two examples where a trend line may be useful.

The next kind of graph is the 'norm' chart, which is a sequential plot of actual consumptions overlaid with a trace representing target consumption levels. The norm chart is of little or no analytical value, but can be useful for illustrating the validity of the method to sceptical colleagues because it is easy to follow. In the illustration of Fig 6, for instance, fair agreement is maintained throughout the history with the exception of the period December '91 to April '92 (and to a lesser extent January to March '93) when actual consumption did not agree with the calculated target.

The pattern of discrepancies can be more readily judged by plotting just the differences between target and actual consumption. This is known as a 'deviance' or 'control' chart (Fig 7). It is useful to sketch in limits of normal variability as indicated, because it helps to differentiate between normal background random variations and serious disturbances. The deviance chart is ideal for staff awareness programmes, because a monthly update shows clearly how they are doing. The game is simply to keep the trace below the upper control limit. Any serious lapse of discipline or plant malfunction causes the trace to breach the upper limit, but the effect of remedial action is seen when it subsequently returns to the acceptable band. See *Case study 2* for an illustration of this.

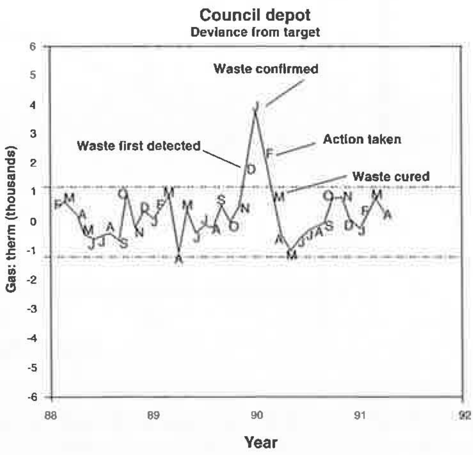
The final transformation is to calculate and plot the cumulative sum of deviance from target. This is known as a CUSUM chart (Fig 8).

When performance is substantially on target the CUSUM chart will run horizontal because positive and negative deviations cancel each other out; but when performance is affected by unexplained excess consumption the positives will predominate and the value of the CUSUM will increase continuously.

Case study 2

A borough council's buildings were routinely monitored by an outside consultant. In December 1989 excessive consumption was noted, slightly outside the 1,200 therm (130 GJ) band of normal random variance appropriate for the building.

An alert was issued to the manager, who unfortunately took no action, and in January 1990 excess consumption reached nearly 4,000 therms (420 GJ). During February, the consultant visited the site and quickly discovered that the timeswitch was set (wrongly) for continuous occupation. Rectifying this minor error halved the fuel consumption of the building at a saving of £10,000 per year.



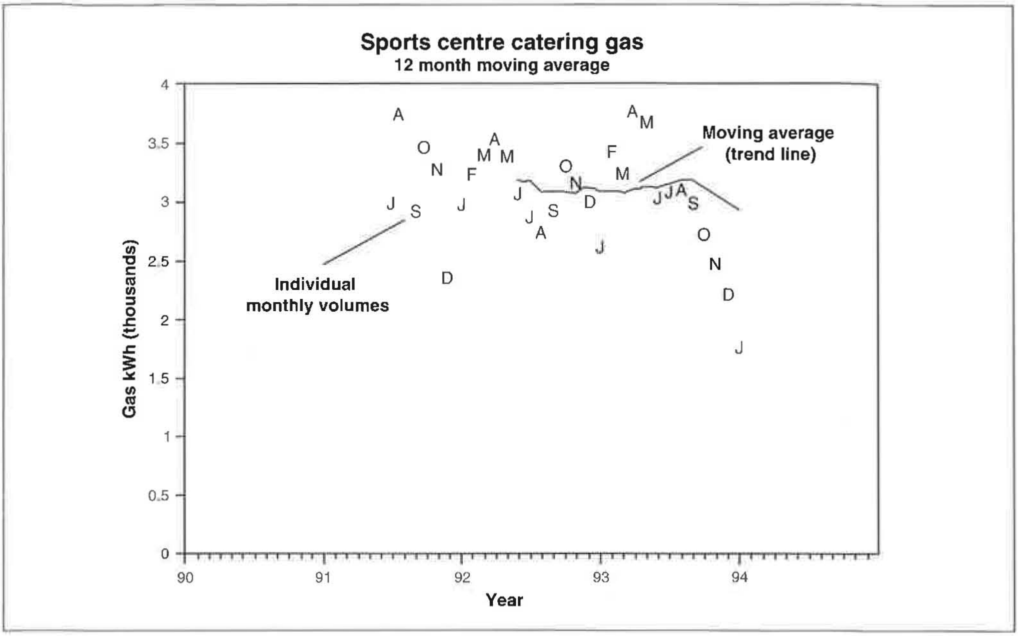


Fig 5 Gas used for catering is seasonal, but not always related to any other measurable factor. The annual moving average reveals the underlying trend despite wide short-term variations

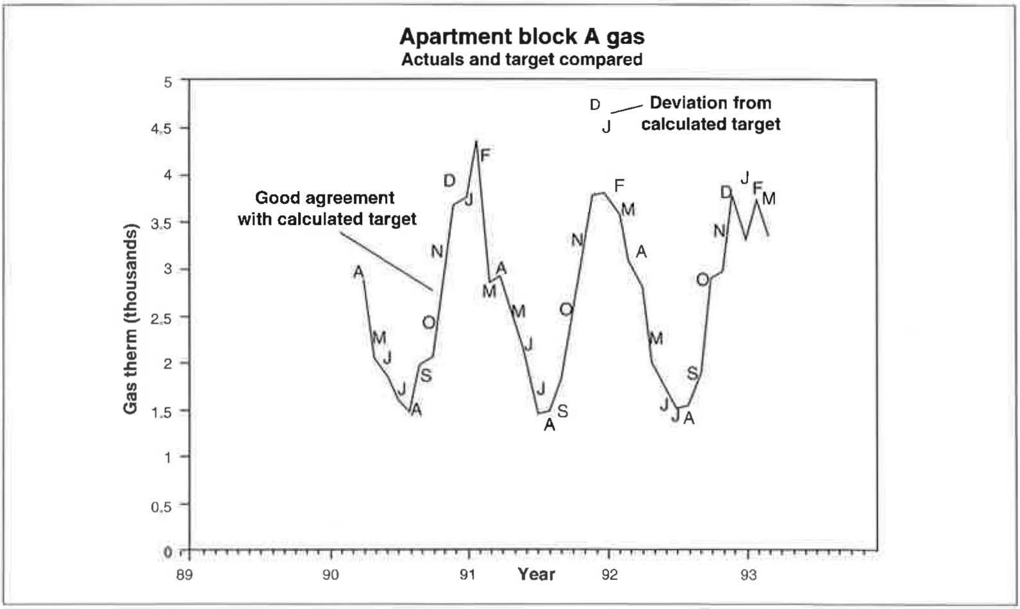


Fig 6 The norm chart plots the actual monthly consumption (represented by initial letters of the months) and superimposes the target consumption (solid line) which has been calculated from the target performance characteristic. Here there is good agreement much of the time, but noticeable discrepancies from December 1991 and January 1992

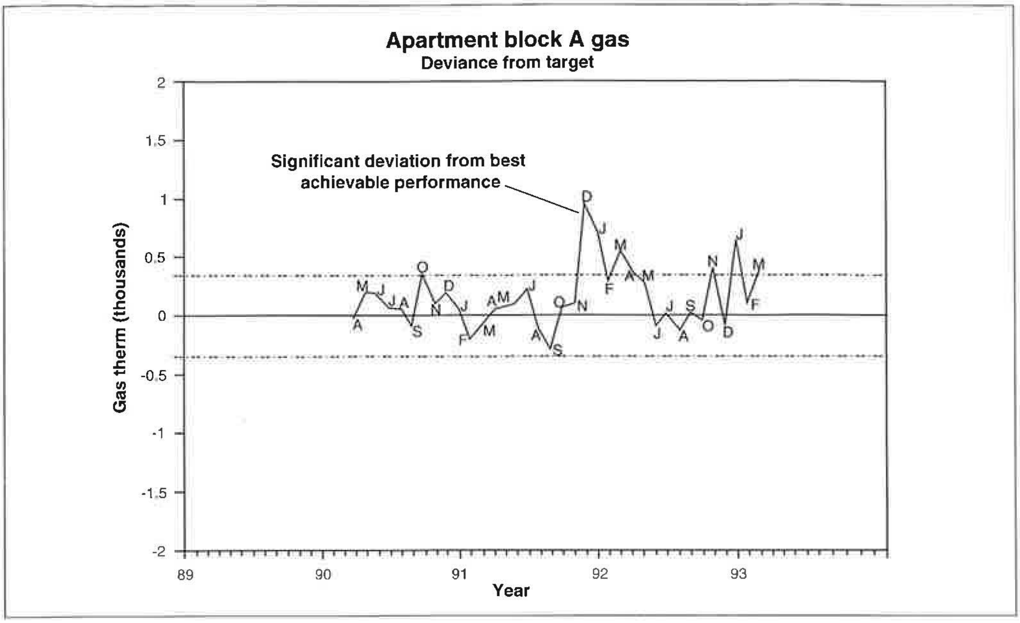


Fig 7 The discrepancy between actual consumption and the calculated target is here plotted as a deviance chart on which control limits have been superimposed. Periods of excess consumption are emphasised in this way, and a return to correct operation can be seen

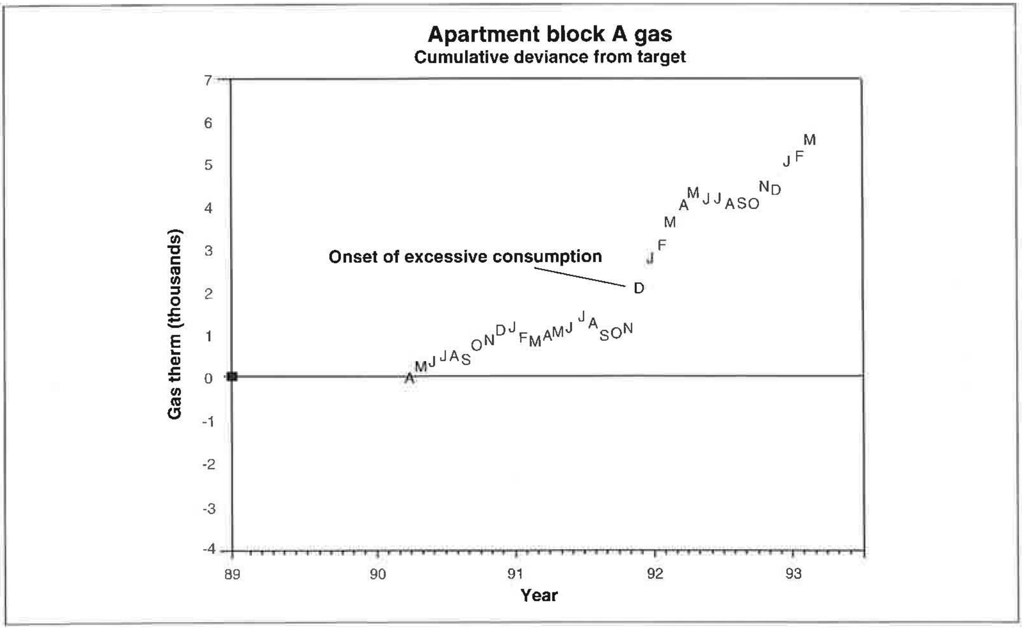


Fig 8 If the successive monthly deviations of Fig 7 are added cumulatively, the result is this CUSUM chart. A horizontal trend signifies on-target operation; changes in direction represent the dates of changes in performance

4. Diagnosing changes in performance

Usually the occurrence of unexpected and unexplained excess consumption is sufficient in itself to enable the cause of waste to be identified and rectified. Merely knowing that waste has started to occur may be enough to prompt enquiries leading to a solution.

Sometimes, however, the cause of excess expenditure is not readily identified and the waste may thus become persistent. When this happens, valuable additional information may be gleaned by analysing the CUSUM chart.

As explained in the previous section, the CUSUM trace runs horizontal in periods when performance is on target but adopts a different gradient when performance is off target. From this, it follows that bends in the trace occur whenever there are changes in performance. Knowing the date when performance changed is a great help when diagnosing the cause. In Fig 8 for example, it could be seen that the behaviour of the heating system changed in December '91, reverted to correct performance in June '92 and then failed again in November '92 and January '93.

What else can we discover? We know that performance during the period December '91 to May '93 was different from what had previously been achieved; identifying these points on the scatter diagram enables us to fit a straight line through them alone, the new line representing the nature of the change in performance (Fig 9).

The change in slope in Fig 9 indicates a change in the weather-related heat demand; perhaps an unauthorised increase in space temperature or an increased ventilation rate. If the line's gradient had remained the same, but its intersection with the vertical axis had moved upward, this would indicate an increase in the fixed (non-weather-

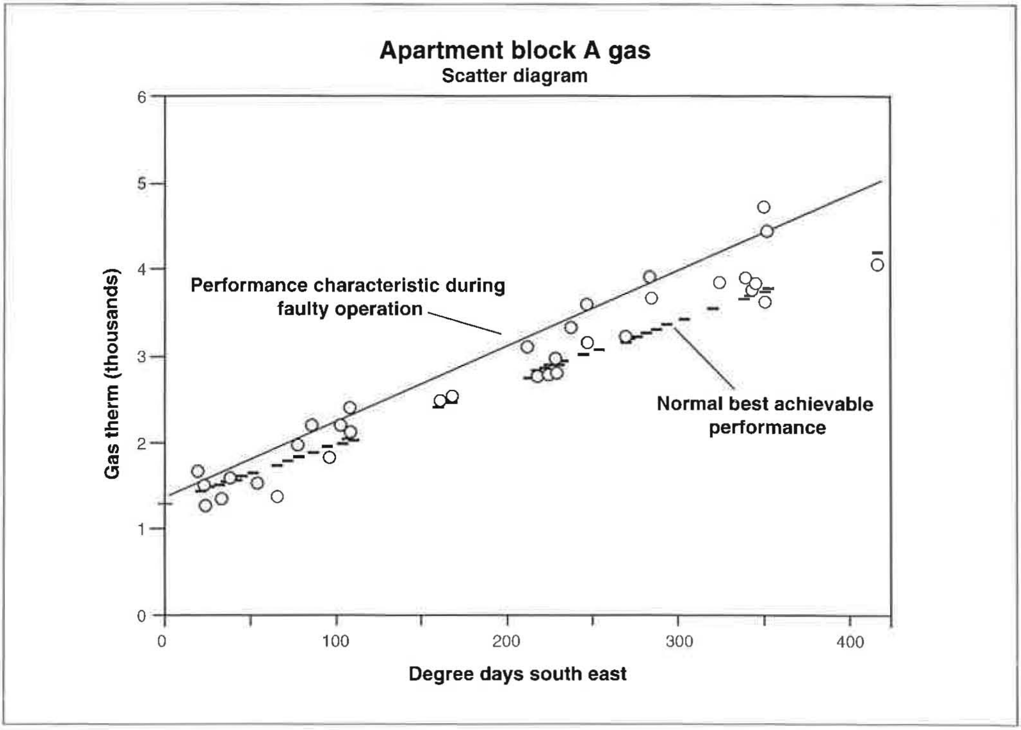


Fig 9 Using the CUSUM chart to distinguish periods of incorrect operation allows the affected months to be isolated and analysed separately. From this, one can gain an impression of the operating characteristic which prevailed while the fault was current. Here, the excess consumption is weather-related

related) fuel demand. Such a transition can be seen in Fig 10, which shows how a sister building behaved over the same period. It suffered unexplained increases in non-weather-related consumption, such as might be caused by heat loss through an idle boiler, or domestic hot water going from timed to continuous operation.

Some kinds of fault impose a constant extra demand for energy; some impose a variable demand proportional to production throughput or other external influence. Some kinds of fault increase both the fixed and variable consumption. For the specific process you are interested in, the particular change you observe through this kind of analysis will suggest likely explanations and help to eliminate blind alleys.

5. More advanced target setting

So far we have confined ourselves to the simple case where (a) consumption volume is determined by a single factor and (b) the relationship between the two approximates to a straight line. These assumptions adequately cover the great majority of normal monitoring situations, but occasionally refinements are needed. The most usual refinement is to provide for a second determining factor. For instance the electricity consumption in a factory may be primarily determined by production volume but it may also be influenced by the varying monthly hours of darkness; in electrically-heated buildings equipped with comfort cooling, the monthly electricity consumption may vary with both heating and cooling degree day values. The fuel used to heat a swimming pool may vary with heating degree days and attendance figures; the fuel needed to heat a workshop may be dictated by degree day values and hours per month worked.

If the two determining factors are A and B, the target consumption T is given by the formula $T = k_0 + k_1A + k_2B$ where k_0, k_1, and k_2 are constants unique to the process being monitored.

The values of k_0, k_1 and k_2 can sometimes be found by experiment. For example in *Case study 3*, one driver's mpg figure was estimated by making measurements between the first and last refuelling stops on long trips away. Assuming no fixed monthly fuel consumption ($k_0 = 0$) the other driver's mpg figure can be arrived at by difference. Otherwise, if you have encountered the statistical

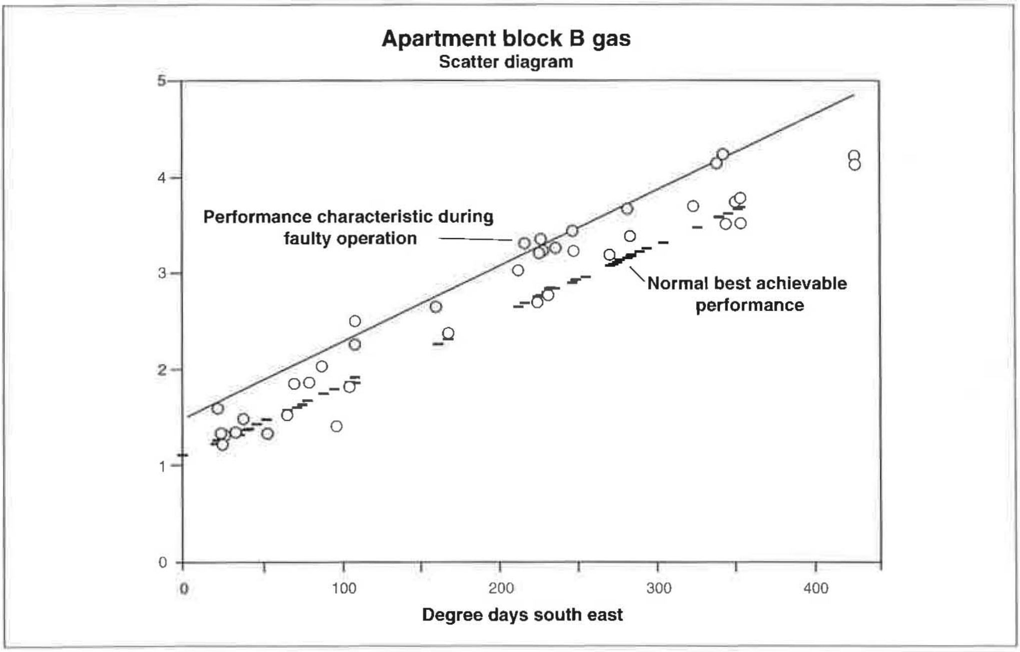


Fig 10 In this example, in contrast to Fig 9, excess consumption is the same under all weather conditions

technique called regression analysis (which is now a standard tool in modern spreadsheet programs) you will know that this provides an alternative way of determining k_0, k_1 and k_2.

The idea of having two determining factors can be extended to three, four, or more, but the improvement in accuracy is rarely sufficient to justify the labour. Sometimes it is valid to assume a single determining factor, but not a straight-line relationship. On one particular papermaking machine it was discovered that the relationship between electricity used and production volume P gave a nonsensical result, predicting a negative consumption at very low throughputs. When the target was altered to refer to P^2 (the square of

Case study 3

Multiple determining factors

Sometimes it is not possible to express the target energy consumption as a straight-line relationship with a single determining factor. We can illustrate this point using monthly fuel and mileage records from a car which was shared between two drivers.

The records of monthly fuel purchases and mileages are given in the table below.

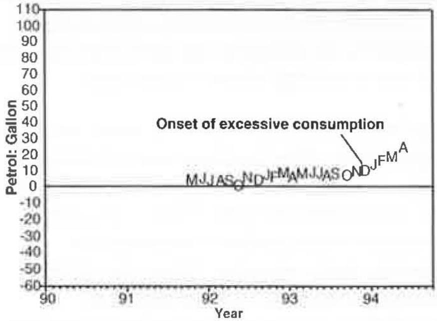
Note: these columns adjusted to 30.5 - day basis

Period	Actual volume (standard international units)	Driver A mileage	Driver B mileage	Adjusted volume gall	Target volume	Deviance	Cusum	Twelve period average
1 92	0.00	0.00	0	0	NA	NA	0	NA
2 92	0.00	0.00	0	0	NA	NA	0	NA
3 92	0.00	0.00	0	0	NA	NA	0	NA
4 92	0.00	1870.67	0	0	NA	NA	0	NA
5 92	61.20	1761.13	404.37	60.21	56	4	4	NA
6 92	53.34	728.83	1142.73	54.23	54	0	4	NA
7 92	49.85	1170.81	686.74	49.04	50	-1	4	NA
8 92	14.89	245.97	310.90	14.65	15	-1	3	NA
9 92	50.73	1636.83	376.17	51.57	52	-1	2	NA
10 92	45.23	413.23	1190.48	44.50	46	-2	1	NA
11 92	34.21	518.50	568.32	34.78	30	5	5	NA
12 92	39.55	708.39	771.35	38.91	41	-2	3	NA
1 93	55.65	1436.45	507.68	54.75	51	4	7	NA
2 93	77.45	2559.82	742.90	84.37	86	-2	5	NA
3 93	58.07	1761.13	339.44	57.14	54	3	8	NA
4 93	66.23	1199.67	1305.4	67.34	69	-2	6	50.96
5 93	35.61	531.29	683.79	35.04	34	1	7	48.86
6 93	44.52	1342.00	335.50	45.26	44	2	9	48.11
7 93	59.72	1672.58	603.11	58.76	60	-1	8	48.92
8 93	76.59	1879.19	998.62	75.36	77	-2	6	53.98
9 93	74.92	2175.67	701.49	76.17	75	1	7	56.03
10 93	55.59	1711.93	390.59	54.69	55	0	7	56.88
11 93	31.24	701.50	430.05	31.76	30	1	9	56.62
12 93	47.16	964.19	695.59	46.40	45	1	10	57.25
1 94	63.33	1288.87	906.14	62.31	59	3	13	57.88
2 94	44.54	1030.69	584.76	46.85	43	4	16	54.76
3 94	51.57	1163.92	668.96	50.74	50	1	17	54.22
4 94	62.46	2374.64	-71.13	63.50	57	6	24	53.90
5 94	0.00	0.00	0	0	NA	NA	24	NA
6 94	0.00	0.00	0	0	NA	NA	24	NA
7 94	0.00	0.00	0	0	NA	NA	24	NA
8 94	0.00	0.00	0	0	NA	NA	24	NA
9 94	0.00	0.00	0	0	NA	NA	24	NA
10 94	0.00	0.00	0	0	NA	NA	24	NA
11 94	0.00	0.00	0	0	NA	NA	24	NA
12 94	0.00	0.00	0	0	NA	NA	24	NA

A single target for mpg is not the best approach in these circumstances. Instead, the target must be weighted according to the respective shares of mileage. For the case in question, the expected fuel consumption F in any given month was expressed as $F = 0.025\ M_A + 0.03\ M_B$ where M_A and M_B were the monthly mileages attributable to drivers A and B respectively.

Deviations from expected fuel consumption were plotted as a CUSUM chart and showed a tendency to excess consumption from December 1993 (readers are invited to work through this example for themselves to verify the result). The cause was traced to two spark plugs not being tightened during a routine service at the end of November 1993.

Car fuel consumption
(licence number D95 BDG)
Cumulative deviance from target



Driver A drove predominantly long journeys and was known to achieve an average of approximately 40 mpg (0.025 gallon per mile), whilst driver B, who mainly did short journeys, used about 0.030 gallon per mile on average. Their monthly shares of mileage varied quite widely; for example in September and October 1992 the ratios were about 4:1 and 1:3 respectively.

production volume), a more reasonable-looking relationship resulted, with a finite electricity demand at zero throughput, which is what one would expect. The choice of P^2 as a proxy determining factor was derived from engineering intuition, based on the idea that the frictional losses in the machine's drive trains increase not in direct proportion to speed but as the square of speed (or something like it). It may not be precisely correct; that does not matter here. The use of a straight-line relationship with P^2 was merely a convenient way of implementing a curved performance characteristic which reduced errors somewhat and prevented nonsensical results at low throughputs.

Generalising from this idea, the single determining factor which it is so convenient to employ could in fact be an index figure derived by a calculation of any degree of complexity, based on any number of process variables. In targeting the energy used per week in a batch furnace for instance, one could take into account the number and weight of charges, using a formula to reduce all these data to a single index of energy demand.

A very common form of this procedure occurs where the same machinery is used to make a mix of different products in varying amounts. If the energy intensity of each different product is known, their individual monthly production volumes can be added, but with weighting factors applied, so that the result is expressed in equivalent units of an index product. For instance it is common in the brewing industry to express production volumes in 'equivalent hectolitres'.

When the production mix is so erratic and varied that weighting factors cannot be calculated, it is possible to resort to 'back-to-back' comparisons. For example, the steam used in a papermaking machine can be related to the electricity used, and each can be tracked relative to the other.

There was once a case where the water use in two neighbouring office buildings was substantially steady, but with coincidental periods of slightly high consumption in both. These coincidental movements were attributed to changes in prevailing mains pressure. When one of the buildings developed exceptionally high consumption, the excess was found to correlate well with changes in the volume of water taken next door. From this it was possible to conclude that the leak itself was subject to mains pressure, and thus had to be in a mains-fed rather than a tank-fed circuit. A tank-fed leak would have taken excess water at a constant rate.

6. Software assistance

Although the procedures described in this booklet are simple enough to implement as a paper-and-pencil exercise, most people will prefer to computerise the process to some degree, for example by using a spreadsheet program. More information on how to develop this option can be found in reference 8, and even if you yourself do not have spreadsheet skills, there will very likely be somebody in your organisation who does.

Another alternative is to purchase a monitoring and targeting (M&T) system from one of the suppliers listed in Good Practice Guide 31, Computer-aided Monitoring and Targeting (5). However, when exploring this option, you should bear in mind that some M&T systems (especially those designed for multiple establishments) have a focus on purchasing. They are more concerned with tariff and contract optimisation (prices) than with physical performance characteristics (consumption volume).

To support a waste avoidance regime, you must focus on physical performance and hence you should choose M&T software which works by technical rather than financial analysis (although it ultimately reports results in cash terms).

One test of suitability might be to ask how a given program would handle an electricity submeter feeding a load which varies with two factors: perhaps production tonnage and hours of darkness; or degree days and number of customers through the door; or pieces made and hours run; or whatever combination might plausibly be relevant to your operations. Three features of this question will weed out the less relevant M&T packages.

One is the fact that the subject is a submeter, so it is not associated with a utility account. Another is that there are two factors influencing consumption, not just one; the third is that one of the factors at least is something other than the classical degree days or production volume. You are not looking for any specific answer from the salesman; merely an unhesitating and logical reply.

Cash value of estimated excess consumptions, arranged in descending order

Overspend league table for period 10/90 completed on 8/11/90

Name	Stream and commodity code	Excess £	%
A2MXST01	Main dryers (steam)	1810	2
A2CREL99	Compressors (electric)	505	4
A2FZEL09	Packing department (electric)	324	17
A2FAGA73	Workshop heating (gas)	246	8
DEDEEL31	Derby depot lorry sockets (electric)	200	63
A2B70112	Boilers 7 and 8 (HFO)	97	1
A20FGA35	Offices space heating	63	12
DEDEWA22	Derby depot (water)	49	17
A2MXEL76	Presses (electric)	13	0
DEDEGA32	Derby depot space heating (gas)	-5	10
A2B1GA88	Boiler 1 (gas)	-90	1

Titles of consumption streams for which targets have been set

Deviations from target, expressed as percentages

Fig 11 The overspend league table emphasises the important problems and instantly makes it obvious where remedial investigations are needed

7. Operating a waste avoidance scheme

A user with just a few metered streams of consumption to monitor could conceivably get by using hand-drawn graphs, perhaps just a scatter diagram with a target line and a deviance chart in each instance. But this will not suit anyone with numerous streams to track; even with software assistance it would be too laborious to view and interpret every stream's deviance chart each month (let alone every week if that is the preferred interval). Some form of summary report is needed.

The recommended report is the overspend league table shown in Fig 11. As its name implies, it is a ranked list of excess expenditures. It is simple to calculate, so most competent spreadsheet users could tackle the task with confidence. The steps required are these:

1. For each stream:
- calculate the target energy consumption T for the month concerned by reference to the value of the determining factor A or factors A and B $T = k_0 + k_1A$ (or $T = k_0 + k_1A + k_2B$ if there are two determining factors)
- calculate the actual consumption this month, C
- compute the excess cost E by reference to the marginal unit price P:$E = P(C\ T)$
The marginal unit price is the amount you would pay to purchase each extra unit over and above your current needs.

2. Rank all the targeted streams in descending order of excess cost (E).

The beauty of the overspend league table is that the significant problems float to the top. It provides both an exception report and a priority list in a compact format, and the potential cash value of remedial action can immediately be seen.

A waste avoidance scheme is only as good as the data which goes into it, so it is important to pay attention to data collection. Some basic rules follow.

- Use in-house meter readings wherever possible. Do not rely on your supplier's readings.
- Where supplies are delivered into on-site storage and no meters are fitted, record the residual stock level at the end of each month and set up a foolproof way of registering the volume of every delivery without duplication.
- Take pains to record all relevant determining factors: production volumes, degree day counts for heating or cooling, hours of darkness, and so on.
- When meters are exchanged, always record both the meter readings at the time.

If using a computerised system it is preferable to store the original totalised meter readings - with their dates - and let the computer calculate the meter advance for you. Also, do not break the record at the

Examples of causes of avoidable waste

To assist warming of steam distribution mains during startups, bypass valves are provided. If one of these is inadvertently left open, steam will escape at a more or less constant rate until the next time the plant is shut down and restarted correctly.

Frost protection devices are frequently responsible for waste of electricity. Access ramps with under-surface heaters can fail in the 'on' position with no other perceptible effect except increased electricity use. Electric preheater batteries on air-handling systems may be found to be running all the time, and it is not uncommon for the frost thermostats in toilets to be overridden out of expediency if a fault is suspected.

Time controls are always a vulnerable point. Conventional timeswitches may stop or be overridden, or they may simply be set incorrectly by accident (for example during maintenance). Buildings controlled by energy management systems are no less prone to this problem. Some models of optimum-start control can extend morning preheat periods excessively under certain circumstances.

Panic measures to fix operational problems can lead to waste if appropriate permanent measures are never taken: for example, the fitting of an oversized temporary pump without the proper control interlocks.

Minor control components can cause waste if they fail. The inlet screens on an unattended water treatment works, for example, might be cleaned by an intermittent raking mechanism, with accumulated debris being sluiced through a macerator and compacted for disposal. If the screen parking switch fails, the rake mechanism, the washwater pump, the macerator and the compactor will run continuously: this could easily add 10kW of continuous load where the true demand would only amount to a few minutes' operation a day.

Water leaks and air leaks can occur without any physical sign, as can steam leaks in out-of-the way corners of a factory.

With the general increase in electrical office equipment some buildings (bank and building society branches for example) have been fitted with comfort cooling in the form of independent packaged units. These are notoriously prone to excess electricity consumption. If the temperature set point for cooling is even slightly below the heating set point, both heating and cooling will operate simultaneously and the occupants will not notice any obvious adverse effects.

end of the year; avoidable waste is no respecter of the calendar, the tax year, your accounting year, academic year or any other artificial time partition. Treat the passage of time as a continuum.

It is extremely desirable to prime the system by supplying historical data. Two to three years' worth would be the ideal; it enables targets to be set immediately and may reveal latent faults, which will yield immediate savings.

If monitoring a building on a weekly or shorter cycle, do not rely on degree day values from anywhere too distant; measure your own, using a proprietary logger or a building management system. If monitoring a process which entails an unavoidable percentage of waste (as happens with papermaking because of breaks, edge trimming, and blemishes) use gross production, rather than saleable tonnage, as the determining factor. Energy use is determined by total product volume, whether it is saleable or scrap. But remember it may be possible to set a target for scrap as a percentage and incorporate this in your monitoring regime. Scrap costs you money as well, and unexplained changes in scrap levels signify avoidable expenditure.

8. Investigating overspends

Once a significant overspend has been detected, you will need to establish the true cause before you can take effective remedial action. Often this will involve asking for help from an operator, a maintenance fitter, caretaker, or other person at the "coal face". Yours may be an organisation where shopfloor employees already share 'ownership' of the energy monitoring function, but in a more traditional management environment some detective work will be called for. Approach the task with the following principles in mind.

- Go prepared: take with you any information or evidence you have already collected, and do not lose sight of your purpose.

- Beware of the language barrier: never assume that the subject shares, or even understands, the terminology and jargon that you use. You are presumably a specialist and they an amateur (although from their perspective, the roles are firmly reversed).

- Avoid talking down to the subject - or talking over their head: if you have not met the subject before and do not know the level of their technical awareness, use the early part of the interview to assess it. Listen to the way they describe their duties and the equipment in their charge. They may use terms which you do not understand; ask them to explain them.

- Express your motives positively: do not say 'we have noticed that you often waste energy, and we'd like to find out why'. Instead, say 'we have noticed that some months this process (or building) uses less energy for similar production output (or weather)'.

- Do not promise what you cannot deliver: often the person you speak to will have some other topic they want to talk about (perhaps a long standing grievance). Or they may have an idea for an improvement to the process or building which would require some investment or simply a commitment of time. Although it is tempting to say you will see what you can do, resist the temptation unless you are absolutely certain that you will have both the time and the means to fulfil the promise.

- Establish credibility: fortunately, when you use computer-aided waste detection, credibility is not hard to achieve because, although you may be the 'outsider', you will arrive armed with quite detailed knowledge of the performance characteristics of the plant or building concerned, including past changes in performance. For example, you may be able to display your knowledge by referring to the date of a prior change in performance.

- Don't talk unnecessarily about yourself and your own experiences elsewhere: you want your respondent's views. Talking about yourself takes up valuable time and may make the subject clam up.

- Listen, and show that you are listening: follow what is being said carefully, and with an open mind. Ask the subject to explain anything which you do not understand, or which you feel may be ambiguous. It may also help if,

when you hear something which strikes you as potentially significant, you repeat what was said to be sure of getting the exact words right in your notes.

- Never dismiss anyone's opinion out of hand: everything that is said will have some degree of significance. Remember especially that the subject knows a great deal more than you do about the plant and buildings under their everyday control. You will hear a good deal of apparently contradictory evidence; the time to filter out the useless information is not on the hoof but later, while reviewing all the evidence together.

- Avoid leading questions: you must keep an open mind. Even if you have suspicions, keep them to yourself. You are not there to confirm them. You are there to gather new ideas.

- Do not offer advice or suggestions, unless a mistake is so patently obvious that it must be corrected. If so, avoid creating the impression that you are blaming the subject, and if the mistake is irrelevant to the issue you are investigating, make this clear.

  If the situation arises that the subject asks for your advice, and it is your place to give it, then it would be churlish to refuse and it certainly would not help your investigation. Two points to watch here. Firstly, does the nature of the subject's question give any clues about the problem you are investigating? Secondly, beware of the possibility that the subject is drawing your fire, trying to distract you from something they suspect you would be displeased to discover.

- Do not criticise or make judgements: challenging the subject's way of doing things will not help, unless you are absolutely certain that you have found the root of the problem you were seeking. Your challenge will be based on your preconceptions of how things should work; this violates the principle of keeping an open mind. Secondly, of course, you risk losing the subject's co-operation.

- Be ready to accept that you may be asking the wrong question: for example, you may have found an anomaly in the relationship between energy consumption and production volume over a particular period. You will be primarily interested in what difference in operating procedure might account for the change. Keeping an open mind, you may be prepared to find that it was a mechanical breakdown, perhaps even a metering error, which caused the apparent problem. But just because you have several possibilities in mind it doesn't mean you have all the angles covered. What if the discrepancy was caused by a clerical change in the way production volume is recorded?

- Allay the subject's suspicions: in most people's minds, energy conservation has gradually become associated at worst with expense, discomfort, and lost production, and at best with disruption and cancelled plans.

  The elimination of avoidable waste is not like that. Remember that all you are doing is keeping consumption at the practical minimum required for comfort, production, quality and safety, and all this probably with little or any physical change to plant and buildings. Say so.

  Eliminating the unnecessary consumption of energy means reducing the running times of plant and equipment, which cuts out unnecessary wear and tear, noise and unwanted heat release (colour PC monitors running at empty desks contribute to discomfort in warm weather for example). These can certainly be cited as positive outcomes and in many cases will have a beneficial effect on the circumstances of the individual (far more important, to him, than cash savings for the employer). These days many people are concerned, as responsible citizens, about the environmental impact of their work. Here you are offering them a way in which they, as individuals, can collaborate in a scheme which will have a rapid beneficial effect.

- Acknowledge the subject's help: just a few words of thanks as you leave may be all that is needed; plus a mention to the subject's supervisor if that is relevant. In certain circumstances, especially if the subject has gone out of their way to be helpful, a written note may be appropriate.

9. Measuring savings

Although the central aim of waste avoidance is no more ambitious than to keep consumption down to previous best achieved levels, the analysis techniques which are used have important secondary uses.

One important by-product is the use of CUSUM analysis to evaluate aggregate savings. The CUSUM, it will be recalled, is the cumulative deviance from target consumption, and thus it will measure aggregated savings as well as aggregated waste. Savings are simply measured by the vertical distance through which the trace drops below its previous horizontal trend.

Should the downward progress of the CUSUM chart be interrupted, it may mean that the energy-saving measure in question has stopped working; or it may be a completely unrelated phenomenon. You can discriminate between the two possibilities by noting the slope of the CUSUM chart during the apparent setback. If it is horizontal, it means the process has reverted to its old performance characteristics and this implies a possible failure of the installed energy-saving measure.

If, however, the setback creates a non-horizontal section (as Fig 12 illustrates) the fault is probably unrelated, and its effect can justifiably be discounted. Strictly speaking, such a setback should only be discounted after previous levels of performance have been regained; and even then the reasons for it should be identified to prevent repetition.

Note that the source of savings may just as easily be people-related activities such as improved training, better maintenance procedures, or a motivation and awareness campaign. The CUSUM method is perfect for these situations because it will indicate when the campaign needs refreshing. For more detailed consideration of CUSUM as a tool for proving savings, see reference 3.

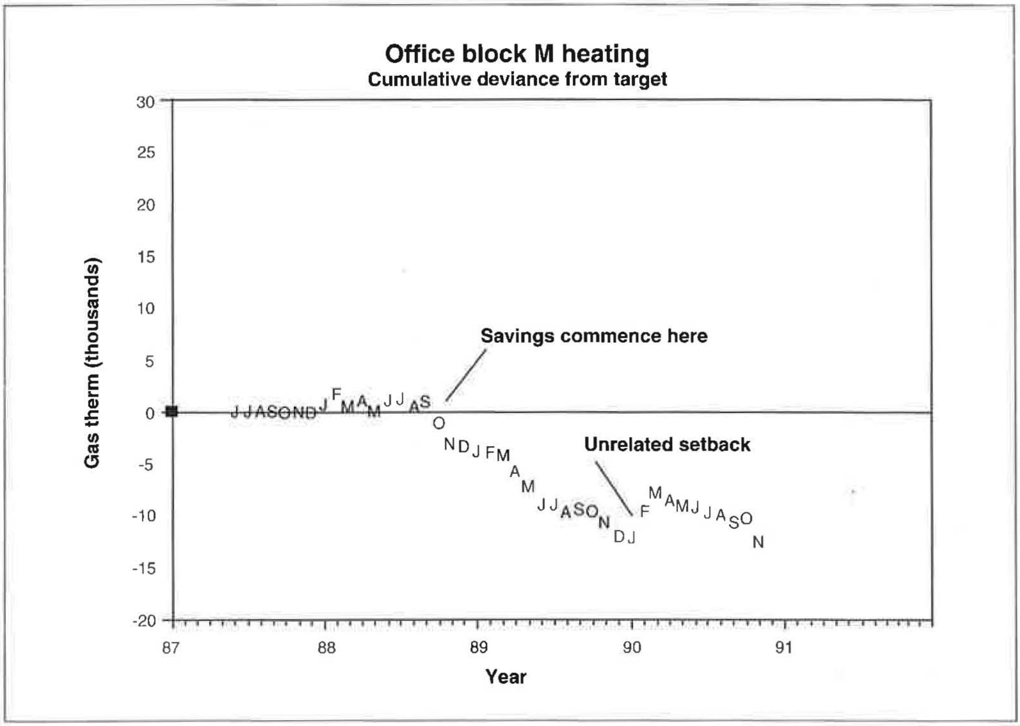


Fig 12 The CUSUM chart is used here to show accumulated savings: they start in October 1988. The serious setback in February and March 1990 cannot be a reversion to former characteristics, because the trend during this period is non-horizontal

10. Other consumables

The principles of waste avoidance are universal. They are not restricted to energy and water. Indeed, certain other consumable commodities can be tracked for signs of unexpected waste very easily because meter readings are available: take for example the humble office photocopier and postage franking machine. Both are fitted with meters showing the number of copies made, or value of postage used, respectively. Consumables, like petrol, which are not metered can be monitored if there is a foolproof system for logging the quantities purchased and estimating the stocks held at each month end.

In a small business it may be helpful to treat the flow of cash as a consumable commodity, watching the expenditure on items such as advertising, travel, and telephones on a monthly basis to detect any upward trends.

When dealing with business expenses such as stationery, waste avoidance techniques can be invaluable in detecting the onset of pilferage because it is almost impossible to start stealing even a small percentage of material without the effect being noticed (in the case of envelopes, for example, consumption could possibly be related to statistics on outgoing mail and postage charges).

Unnecessary energy consumption carries with it a burden of unnecessary global warming and atmospheric pollution, which makes waste avoidance environmentally beneficial as well as profitable. To a degree, the same can be argued for many other consumables as well; they all incur disposal costs, and all entail energy use in manufacture and distribution.

11. A role for conventional vigilance

A waste avoidance scheme along the lines described in this booklet suffers from one limitation. It cannot usually detect waste that has been there all along. It inherently relies on a change occurring while it is in operation (or during any earlier period for which data has been fed in).

Therefore there will always be a role for ordinary watchfulness. People in the workplace should be encouraged to report instances where long-term avoidable waste is occurring. For example, the building services engineer at a building society's headquarters arrived at work one rainy day and found all the front steps except one were dry. On investigation, it was found that trace heating was fitted to prevent icing up; damp had got into the sensors and the heaters were running continuously.

Sometimes it is appropriate to establish a formal framework such as 'waste-watching teams' to encourage vigilance at work. This concept mimics 'quality circles' but with a slightly different focus. Waste avoidance has much in common with quality programmes, because it is a question of spotting defects which arise randomly. Indeed, CUSUM and control charts will already be familiar to some readers as quality control tools.

Waste-watching teams are groups of workplace volunteers who are given time to meet occasionally and discuss ways of reducing costs. They may also be given a budget to cover the cost of bringing in specialist advisers: this is because it is part of their function to evaluate suggestions for themselves, even to conduct experiments if they want. If you are keen to encourage suggestions from the shop floor, it is very useful to be able to restrict and refine them in this way. And it also contributes to staff motivation.

12. Efficiency benchmarks

If you practice waste avoidance as explained in this booklet, you will make savings by ensuring that consumption is kept down at the lowest possible level. The target level is inferred from evidence of previous best consumption, so even if the process or building is unique, the method can still be applied.

When the situation is not unique, though, you will have an opportunity to set even more stringent targets by 'benchmarking' the performance of similar installations.

For example, a college energy manager in Gloucestershire noticed that two similar hostel blocks had different patterns of consumption relative to degree days. One had a substantially higher non-varying component of demand. The cause was traced to an open isolating valve which

was allowing heat to dissipate through an idle boiler. Using the valve correctly saved £6,000 per annum.

An interesting point to emerge from this case was that the average annual fuel consumption per square metre was nearly the same in both buildings; there was nothing there to suggest any scope for improvement.

In general, performance standards based on simple energy ratios (simple kWh per tonne, therm per degree day, etc) can be very misleading for the assessment of individual cases.

This is especially true where an installation has been prone to unexplained excess consumption. A better method of comparison is to establish the minimum consumption characteristic for each individual case and then compare the 'signatures' afforded by the *x-y* scatter diagrams. Different installations can be compared in terms of fixed and variable demands separately, with scaling factors if necessary to account for differences in size.

Remember that you are not restricted to your own estate. Another company in the same business may be willing to share operating data of this kind in order to establish the true scope for improvement.

Finally, it may become apparent that consumption levels are unreasonably high if the volumes are expressed as analogues. For example, if an office housing 200 staff has a summer-time minimum demand for heating fuel of 16 000 kWh per month, this could be challenged as excessive; it equates to two hot baths per person per week.

13. Training, awareness and motivation

Avoidable waste is not only caused by technical failures. It is just as likely to arise from human error or ignorance.

Part of the solution, then, is to pay proper attention to the people dimension by:

- training those who directly influence energy use
- raising awareness of staff at large, perhaps occupants or maintenance contractors as well
- motivating everyone in the organisation to watch out for waste and do what they can to prevent it.

See references 6 and 7 for more detail on this theme.

Suggestion schemes, in-house newspapers, posters, competitions, and waste-watching teams are just some of the resources which you may be able to deploy. Just involving people and listening to their views may be enough to motivate them. Anything that gives them 'ownership' of the energy problem will help even more.

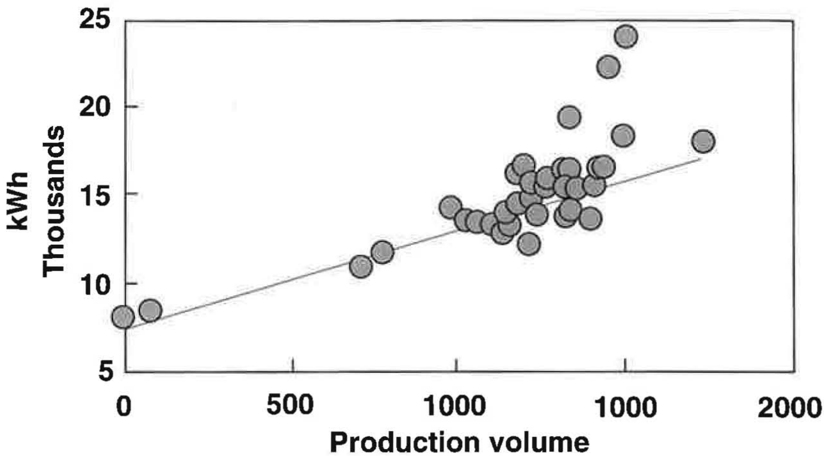
People do not just cause avoidable waste: they can become part of the detection mechanism and, for that matter, part of the solution as well.

References

1. Lyle, Oliver, Efficient use of steam (sect 680). HMSO, 1947.
2. Degree days, Fuel efficiency booklet 7, London, EEO, 1993.
3. Harris, Peter, Monitoring and target setting using CUSUM, Cheriton Technology Management, 1989.
4. Build your own monitoring and targeting system, part 3. Vilnis Vesma *The Resource, Volume 1 No. 5;* IRS Eclipse.
5. Computer aided monitoring and targeting, Good Practice Guide 31.
6. Motivation and awareness, Good Practice Guide 84.
7. Training for energy efficiency, Good Practice Guide 85.
8. "Computer-aided waste detection". Vilnis Vesma *Industrial Management & Data Systems No. 4, 1992;* MCB University Press.

Appendix 1

WORKED EXAMPLE 1: AN INDUSTRIAL PROCESS



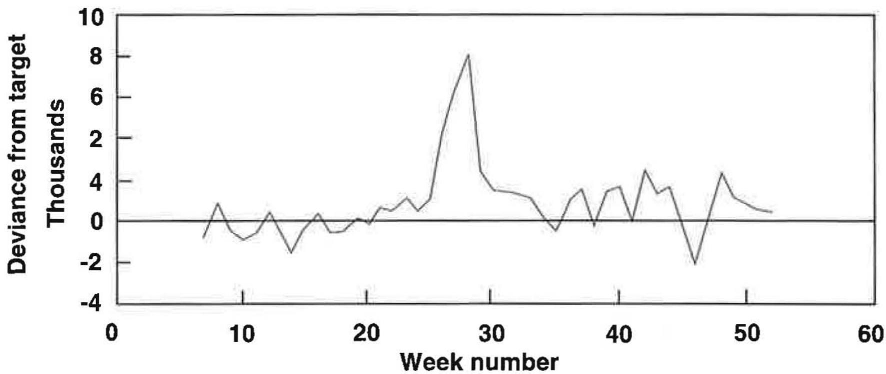
The Scatter diagram (above) is constructed from columns A and B in the table opposite. It is a plot of kWh electricity used each week (column A) against production volume (column B).

Superimposed on the scatter diagram is a target characteristic line. In this example, the suggested target is 7,500 kWh fixed and 5.6 kWh per tonne variable.

Entries in column C are therefore calculated from the formula:

$$7500 + 5.6 \times \text{Column B}$$

which represents the target energy demand. The deviance from target is the difference between column A and column C, and when plotted sequentially give the diagram below.



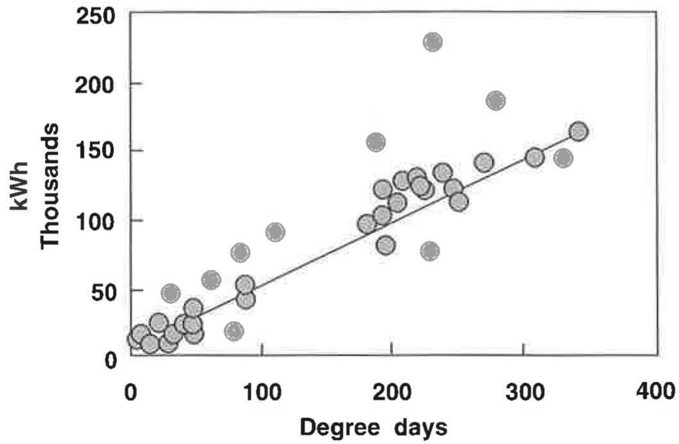
Note: If the deviance chart shows a continuous bias towards under- or over-consumption, the target characteristic line should be dropped or raised accordingly until (ignoring exceptional incidents) the positive and negative deviations balance.

Table for worked example 1

Week & year	kWh used A	Product tonnes B	Derived target C	Deviance from target D
7 93	14 142	1 337	14 989	-847
8 93	15 504	1 261	14 564	940
9 93	13 939	1 245	14 470	-531
10 93	12 962	1 141	13 891	-929
11 93	13 848	1 245	14 470	-622
12 93	14 773	1 222	14 343	429
13 93	14 033	1 328	14 937	-904
14 93	13 372	1 397	15 324	-1592
15 93	11 667	753	11 714	-48
16 93	13 629	1 029	13 261	368
17 93	13 216	1 124	13 795	-579
18 93	13 452	1 160	13 995	-543
19 93	15 244	1 352	15 071	173
20 93	13 460	1 087	13 585	-126
21 93	15 770	1 349	15 052	717
22 93	15 584	1 359	15 109	475
23 93	16 036	1 315	14 865	1171
24 93	15 408	1 325	14 921	487
25 93	16 694	1 441	15 572	1122
26 93	19 511	1 337	14 985	4526
27 93	22 306	1 455	15 649	6657
28 93	24 060	1 503	15 918	8142
29 93	16 505	1 185	14 136	2368
30 93	15 863	1 228	14 378	1485
31 93	16 121	1 274	14 635	1487
32 93	15 956	1 277	14 649	1306
33 93	16 062	1 317	14 873	1189
34 93	15 667	1 412	15 406	261
35 93	11 008	706	11 454	-447
36 93	18 177	1 734	17 212	966
37 93	16 612	1 331	14 953	1659
38 93	13 405	1 102	13 670	-265
39 93	16 513	1 338	14 993	1520
40 93	16 630	1 329	14 942	1688
41 93	14 098	1 150	13 938	160
42 93	18 455	1 496	15 875	2580
43 93	14 306	978	12 975	1331
44 93	16 599	1 320	14 893	1706
45 93	13 511	1 050	13 381	130
46 93	12 243	1 214	14 297	-2054
47 93	14 608	1 187	14 148	460
48 93	16 758	1 202	14 230	2528
49.93	16 690	1 435	15 536	1154
50 93	15 709	1 290	14 721	987
51 93	8 085	0	7 500	585
52 93	8 459	74	7 913	546

Appendix 2

WORKED EXAMPLE 2: HEATING OF A BUILDING



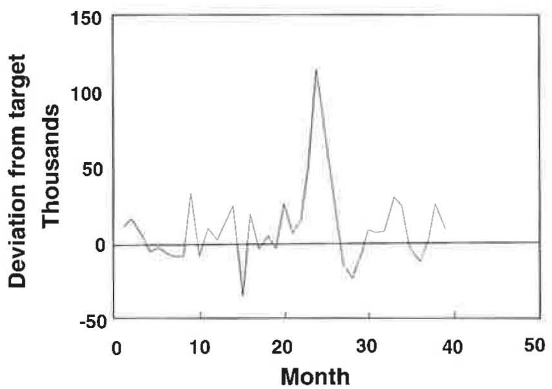
The scatter diagram (above) is constructed from columns A and B in the table opposite. It is a plot of kWh electricity used each month (column A) against degree-days (column B).

Superimposed on the scatter diagram is a target characteristic line. In this example, the suggested target is 7500 kWh fixed and 450 kWh per degree-day variable.

Entries in column C are therefore calculated from the formula:

$$7500 + 450 \times \text{Column B}$$

which represents the target energy demand. The deviance from target is the difference between column A and column C, and when plotted sequentially gives the diagram below.



Note: If the deviance chart shows a continuous bias towards under- or over-consumption, the target characteristic line should be dropped or raised accordingly until (ignoring exceptional incidents) the positive and negative deviations balance.

Table for worked example 2

Month & year	kWh used A	Degree-days B	Derived target C	Deviance from target D
2 88	140 534	271	128 950	11 584
3 88	132 585	239	114 550	18 035
4 88	96 624	182	88 900	7 724
5 88	41 874	88	46 600	-4 726
6 88	23 156	40	25 000	-1 844
7 88	17 251	33	21 850	-4 599
8 88	11 251	27	19 150	-7 899
9 88	20 982	47	28 150	-7 168
10 88	91 606	111	56 950	34 656
11 88	112 975	253	120 850	-7 875
12 88	111 793	205	99 250	12 543
1 89	120 905	248	118 600	2 305
2 89	120 413	226	108 700	11 713
3 89	127 456	209	101 050	26 406
4 89	76 509	230	110 500	-33 991
5 89	56 321	62	34 900	21 421
6 89	25 074	48	28 600	-3 526
7 89	14 472	5	9 250	5 224
8 89	10 011	14	13 300	-3 289
9 89	46 905	30	20 500	26 405
10 89	52 574	87	46 150	6 424
11 89	122 573	224	107 800	14 773
12 89	184 067	280	133 000	51 067
1 90	226 798	233	111 850	114 948
2 90	155 113	190	92 500	62 613
3 90	120 690	194	94 300	26 390
4 90	81 448	196	95 200	-13 752
5 90	19 788	78	42 100	-22 312
6 90	18 245	47	28 150	-9 905
7 90	25 164	20	16 000	9 164
8 90	16 708	7	10 150	658
9 90	35 303	48	28 600	6 703
10 90	75 954	84	44 800	31 154
11 90	129 869	220	106 000	23 869
12 90	143 039	309	146 050	-3 011
1 91	143 039	331	155 950	-12 911
2 91	161 889	343	161 350	539
3 91	120 495	195	94 750	25 745
4 91	102 483	193	93 850	8 633

Titles in the Fuel Efficiency Booklet series are:

1 *Energy audits for industry*
1B *Energy audits for buildings*
2 *Steam*
3 *Economic use of fired space heaters for industry and commerce*
4 *Compressed air and energy use*
7 *Degree days*
8 *The economic thickness of insulation for hot pipes*
9 *Economic use of electricity in industry*
9B *Economic use of electricity in buildings*
10 *Controls and energy savings*
11 *The economic use of refrigeration plant*
12 *Energy management and good lighting practices*
13 *Waste avoidance methods*
14 *Economic use of oil-fired boiler plant*
15 *Economic use of gas-fired boiler plant*
16 *Economic thickness of insulation for existing industrial buildings*
17 *Economic use of coal-fired boiler plant*
19 *Process plant insulation and fuel efficiency*
20 *Energy efficiency in road transport*

Fuel Efficiency booklets are part of the Energy Efficiency Best Practice programme, an initiative aimed at advancing and promoting ways of improving the efficiency with which energy is used in the UK.

For copies of Fuel Efficiency booklets or further information please contact the address below.

Overseas customers please remit £3 per copy (minimum of £6) to ETSU or BRECSU with the order to cover the cost of packaging and posting. Please make cheques, drafts of money orders payable to ETSU or BRECSU, as appropriate.

The Department of the Environment, Transport and the Regions' Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

For further information on:

Buildings-related projects contact:
Enquiries Bureau
BRECSU
Building Research Establishment
Garston, Watford, WD2 7JR
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

Industrial projects contact:
Energy Efficiency Enquiries Bureau
ETSU
Harwell, Oxfordshire
OX11 0RA
Tel 01235 436747
Fax 01235 433066
E-mail etsuenq@aeat.co.uk

Internet **BRECSU** – http://www.bre.co.uk/bre/brecsu/
Internet **ETSU** – http://www.etsu.com/eebpp/home.htm

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R&D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting etc.